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甘肃崖湾—大桥金锑矿整装勘查区 1∶50 000 矿产资源潜力评价数据集

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摘要：甘肃崖湾—大桥地区金锑矿整装勘查区 1∶50 000 矿产资源潜力评价数据集包括：综合建造构造图、成矿要素图、预测要素图、预测成果图等。应用最新资料，对区内建造构造进行梳理。以金、锑矿为主要矿种，重点以“三位一体”找矿预测理论为基础，完成大桥金矿、坪定金矿、崖湾锑矿的研究，划分其成因类型、预测类型，总结区域成矿规律，建立区域预测模型，圈定最小预测区 42 个，金矿预测资源量 560 774.59 kg，锑矿预测资源量 737 241.43 t。数据集的建立反映了整装勘查区 1∶50 000 矿产资源潜力评价的示范性成果，总结探索出其研究思路、工作方法、工作流程、预期成果及成果表达等内容，对该类型潜力评价工作具有一定的参考意义。

关键词：潜力评价；三位一体；金矿；锑矿；预测资源量；数据集；1∶50 000；崖湾—大桥整装勘查区；甘肃

数据服务系统网址：http://dcc.cgs.gov.cn

1　引言

原国土资源部关于《全国地质找矿“358”行动纲要》明确指出要建立公益性地质工作拉动机制。为制定国家矿产资源规划，中国地质调查局以整装勘查区为对象，以潜力评价为手段，全面摸清整装勘查区矿产资源家底，为矿产地质调查和矿产勘查指明方向，为国家矿产资源的战略规划及保护利用，以及为生态文明建设提供基础数据和科学依据。甘肃崖湾—大桥地区金锑矿整装勘查区是西秦岭地区主要的金矿集中区，也是陕甘川“金三角”的重要组成部分。该地区处于这一特殊的成矿环境，也因此成为了近年来实现金、锑矿找矿突破的重点区域。随着对该区成矿特征认识程度的提高，找矿成果

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较为突出。但在找矿方向由矿床外围向全区及深部拓展的过程中，一些新的地质问题也逐渐显现，影响到勘探工作部署。因此在甘肃省崖湾—大桥地区设立整装勘查区矿产资源潜力评价示范项目，开展找矿预测，圈定找矿靶区，评价资源潜力，提出下一步找矿工作部署建议，同时，建立原始及成果资料数据集。

甘肃省崖湾—大桥地区金锑矿整装勘查区位于秦岭—大别新元古代—古生代造山带之白龙江隆起带与阿尼玛卿裂陷沉积区东段 (图 1)❶，岷县—宕昌—两当深大断裂和舟曲—成县—徽县区域断裂穿过本区，由这 2 条断裂将夏河—礼县、碌曲—成县和迭部—武都 3 个逆冲推覆构造带自北向南分割开，在武都—天水一线呈弧顶向南的弧形分布 (图 2；赵彦庆，2004)。整装勘查区东西横跨于该弧形构造带轴线位置，研究者通过弧形构造带对西秦岭金矿的控制作用研究，认为该弧形构造带对金矿的控制作用明显 (殷先明，2009)。

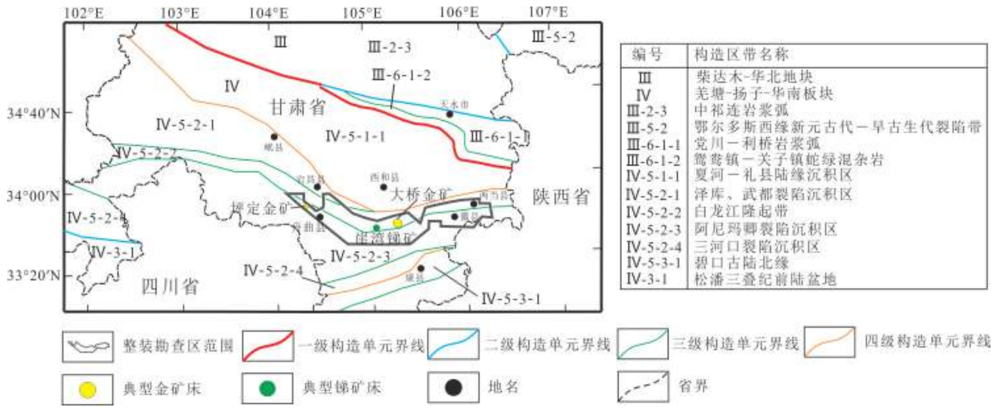

图 1　崖湾—大桥整装勘查区大地构造位置图 (据《甘肃省区域地质志》，2016)

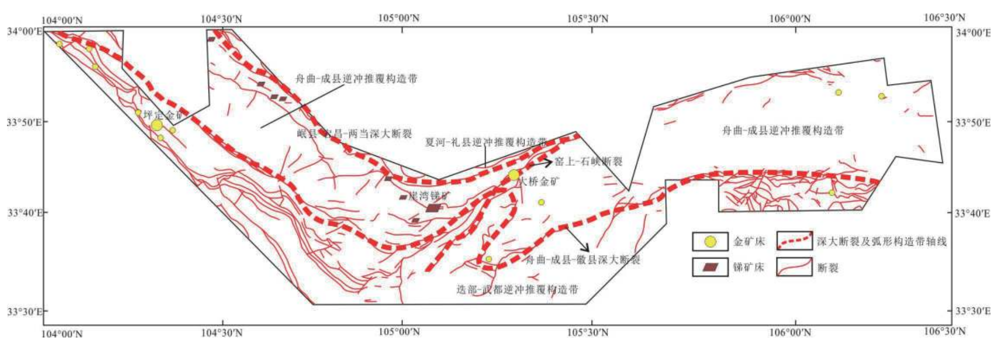

图 2　崖湾—大桥整装勘查区构造及矿产分布图

区内的海–陆相沉积建造系统发育较齐全，其中以海相复理石沉积建造为主要建造类型。三叠系呈东西—北西西向展布于整装勘查区北部，整体为一套复理石建造，岩性组合为碎屑岩→砂岩和粉砂岩、泥灰岩→千枚岩和板岩及碳酸盐岩→泥灰岩、灰岩和白云岩，该套地层是区内层控–热液型金矿的重要含矿地层。南部发育古生代地层，为一套经历了低绿片岩相浅变质作用的海相复理石碎屑岩、碳酸盐岩和硅质岩沉积建造。白垩系、古近系、新近系零散分布于以北东向为主的陆相断陷构造盆地内，为一套红色磨拉石沉积建造（杜远生，1997）。

通过对整装勘查区进行地表的观测，岩浆岩呈小规模零星出露，但是本次工作通过化探、物探等手段推断了大量隐伏侵入岩。值得一提的是通过收集深部地震工作的研究

成果（李清河，1991），笔者认为在宕昌—通渭—静宁—礼县范围内，存在着一系列近于平行的北北东向深部大断裂。是岩浆侵入的良好通道，可能也证明了该构造–岩浆岩带的存在。与成矿关系最为密切的岩浆岩属中酸性侵入体，主要为印支—燕山期岩体(张翔等，2017)。

区内矿产以金、锑为主，已发现的矿床呈带状规律性分布。其中比较重要的有大桥超大型金矿、崖湾大型锑矿、坪定中型金矿，小型矿床有羊里尾沟金矿、水眼头锑矿、安房坝金矿等。所有规模金、锑矿床均处于北东向或北西向隆起的边缘或区域性断裂一侧。

崖湾—大桥地区地区金锑矿整装勘查区 1∶50 000 矿产资源潜力评价数据集（张家瑞等，2020）基本信息简表如表 1。

表 1　数据库 (集) 元数据简表

条目	描述
数据库(集)名称	甘肃崖湾—大桥金锑矿整装勘查区1∶50 000矿产资源潜力评价数据集
数据库(集)作者	张家瑞，甘肃省地质调查院，负责项目组织实施及数据集建立 宿　虎，甘肃省地质调查院，负责遥感类数据集 于祥龙，甘肃省地质调查院，负责地质类数据集 高永伟，甘肃省地质调查院，负责矿产类数据集 蒋　文，甘肃省地质调查院，负责物探类数据集 刘元平，甘肃省地质调查院，负责化探类数据集李增，甘肃省地质调查院，负责地质类数据集 李永胜，中国地质调查局发展研究中心，自然资源部矿产勘查技术指导中心，负责矿产类数据集
数据时间范围	2018—2019年
地理区域	西秦岭地区，E 104°00′ ~ 106°29′，N 33°30′ ~ 34°00′
数据格式	*.wl，*.wt，*.wp，*.docx
数据量	1.2 GB
数据服务系统网址	http://dcc.cgs.gov.cn
基金项目	中国地质调查局地质调查子项目“甘肃崖湾—大桥地区金锑矿整装勘查区1∶50 000矿产资源潜力评价”(项目编号：0747-1861SITCN150-66)
语种	中文
数据库(集)组成	主要由整装勘查区综合建造构造图、成矿要素图、预测要素图、预测成果图、成矿规律图、勘查工作部署建议图(MapGIS格式)组成

2　数据采集和处理方法

2.1　数据基础

甘肃省崖湾—大桥地区金锑矿整装勘查区 1∶50 000 矿产资源潜力评价系列图件以 2018 年由自然资源部矿产勘查技术指导中心组织编制的《整装勘查区 1∶50 000 矿产资源潜力评价技术指南 (初稿)》为基本要求，以“三位一体”勘查区找矿预测理论为指导，以整装勘查区范围内的全国矿产资源潜力评价、矿产地质调查、矿产远景调查、区域地质调查原始资料为基础。采用坐标系统为：1954 年北京坐标系，1985 年国家高程基准，2000 国家大地坐标系 (CGCS 2000)。应用数字填图系统 (DGSS)、MapGIS 等计算机软件进行数据处理与图件编制。工作比例尺为 1∶50 000。

2.2　资料收集情况

整装勘查区涉及 22 个 1∶50 000 标准地质图幅，工作面积约 5 613.84 km^2，针对整装勘查区范围收集的资料，主要以 1∶50 000 矿产地质调查、矿产远景调查、区域地质调查资料为主 (成果资料及所有原始资料)[❷–❽]，用 1∶100 000 或 1∶250 000 资料补充，并在工作开展过程中及时进行资料更新，此外使用化探原始数据 18 209 条，其中 1∶50 000 数据 17 831 条，1∶200 000 数据 378 条等。

基于上述资料，编制整装勘查区建造构造图、成矿要素图、预测要素图、预测成果图、成矿规律图、勘查工作部署建议图等系列图件。

2.3　地球物理和地球化学数据处理方法

2.3.1　1∶50 000 航磁数据处理

该地区以往航磁数据网格大多为 2 km × 2 km，本次收集到 2015—2017 年石家庄核工业航测遥感 500 m × 500 m 网格数据，因此有必要实现整装勘查区 1∶50 000 航磁数据的整理集成。

首先，对不同格式的航磁数据进行调平、拼接，采用 Kriging 法形成间距为 500 m × 500 m 的网格数据；然后，利用 GeoIPAS 4.0 软件对网格化文件进行分块变纬度化极、化极垂向一阶导数、解析延拓等位场转换处理，从而得到航磁 ΔT 异常图、航磁 ΔT 化极平面图、航磁 ΔT 化极垂向一阶导数图和航磁 ΔT 化极剩余异常图等图件。通过对比磁场平面特征与已知矿床分布的对应关系，结合基础地质、化探、遥感等资料，总结构成区域控矿的地质–地球物理标志，划分找矿远景区带。

2.3.2　1∶50 000 地球化学数据处理

本次收集整理区内 1∶50 000 化探资料，源自 18 209 个数据点。通过检查校正原始数据，计算浓集系数 (Kk) 与变异系数 (Cv)2 个参数，结合区内地质矿产背景，确定 Au、Sb、As、Hg、Bi 等元素成矿潜力大，为主要的成矿元素。

采用数理统计法确定异常下限 (T)，$T=X+2S$，其中 X 和 S 分别为背景场的均值、标准离差，结果见表 2。

圈定 Ag、As、Au 等 15 个元素的单元素异常 597 处，圈定综合异常 59 处，其中甲类异常 9 处 (甲 1 类异常 4 处，甲 2 类异常 5 处)，乙类异常 21 处 (乙 2 类异常 3 处，乙 3 类异常 18 处)，丙类异常 29 处 (丙 1 类异常 7 处，丙 2 类异常 7 处，丙 3 类异常 15 处)。对每个综合异常编制剖析图并填写异常登记卡。同时依据组合异常图推测隐伏岩体 2 处。

2.3.3　遥感数据处理

遥感数据采用新收集的高分一号、高分二号数据源，较以往采用的 ETM 数据，数据时间更新、精度更高。为突出影像中有效信息，使用不同波段组合，并采用图像增强、融合、空间滤波等方法，制作与整装勘查区底图同比例尺真彩色合成影像与标准假彩色遥感影像图。

2.4　主要图件编制方法

2.4.1　综合建造构造图

利用所收集的区内最新矿产地质图进行初步拼接后，通过对资料分析筛选，结合区内现有的图切剖面及已查明的大桥金矿、崖湾锑矿、坪定金矿等典型矿床研究成果，系

表 2　异常下限计算表

元素	样品总数/个	剔除特高、特低值后(地球化学背景场)			异常下限
		样品数/个	平均值(X)	离差(S)	
Cu	18209	16673	26.7818	8.8293	44.44
Pb	18209	17085	28.3936	7.4865	43.37
Zn	18209	16172	93.458	27.2119	147.9
Ag	18209	16570	91.7739	41.266	174.3
Mo	18209	16297	1.1399	0.5971	2.334
Sn	18209	17218	3.4372	0.9004	5.24
W	18209	17347	2.3939	1.0269	4.45
Mn	17615	16665	707.971	214.2623	1136.5
Ba	16971	16004	483.4528	132.9016	749.3
As	18209	16872	13.6425	8.3916	30.43
Sb	18209	16346	1.6418	1.1453	3.93
Bi	18209	16372	0.3295	0.0835	0.497
Cd	16282	14956	0.2516	0.1297	0.51
Au	18209	16534	1.2887	0.7736	2.836
Hg	18209	17537	108.8115	144.7213	398.3

注：Au、Ag、Hg含量单位为$\times10^{-9}$，其他均为$\times10^{-6}$。

统划分出整装勘查区沉积岩建造、侵入岩建造等。对地质界线进行核实修正，并依据岩性组合及产状特征，填充岩性花纹。为确保预测工作的可靠性，选择穿过典型矿床、垂直地层的走向为剖面线方向编制剖面图。通过典型矿床建造构造及区域建造构造的分析梳理，确定大桥金矿的含矿建造为三叠系滑石关组薄层泥–粉砂质灰岩建造，崖湾锑矿的含矿建造为三叠系大河坝组泥灰岩建造，坪定金矿的含矿建造为泥盆系下吾那组碳酸盐岩夹泥砂岩建造。

2.4.2　成矿要素图

2.4.2.1　矿产预测类型的划分

通过区域成矿规律和典型矿床研究，确定研究区的主攻矿种为金、锑矿。崖湾—大桥整装勘查区矿产预测类型划分如表 3。

表 3　甘肃崖湾—大桥金锑整装勘查区矿产预测类型划分表

二级分类	三级分类	成因类型	预测类型
岩浆作用矿床	岩浆期后(中)低温热液型矿床	层控–热液型	大桥式层控–热液型金矿
		构造–热液型	坪定式构造–热液型金矿
			崖湾式构造–热液型锑矿

2.4.2.2　成矿要素分析及成矿模式图的建立

全面收集整装勘查区典型矿床 (大桥金矿、崖湾锑矿、坪定金矿) 及区内其他矿床 (点) 的研究资料，运用叶天竺研究员提出的“三位一体”勘查区找矿预测理论 (叶天竺等, 2014, 2017)，分析梳理出整装勘查区内 3 类典型矿床成矿地质体、成矿构造及成矿结构面和成矿作用特征标志等。同时，深大断裂严格控制建造的分布，矿床的分布又与建造有密切关系，因此深大断裂对成岩及成矿起到重要的控制作用，控制和影响了各类

内生矿床的形成和时空分布。

由此建立整装勘查区成矿要素表 (表 4) 及区域成矿模式图。

2.4.2.3　成矿要素图编制

以综合建造构造图为底图，以成矿要素分析成果为基础，保留必要、重要成矿要

表 4　甘肃崖湾—大桥金锑整装勘查区成矿要素表

成矿要素		描述内容	分类
成矿地质背景	大地构造位置	北部为白龙江隆起带沉积区，南部为阿尼玛卿裂陷沉积区	重要
	区域成矿带	北部为碌曲—徽县成矿亚带；南部为迭部—陇南成矿亚带	重要
	岩浆岩带	北部为白龙江隆起带构造岩浆岩段，南部为阿尼玛卿裂陷沉积区构造岩浆岩段	重要
	构造环境	秦岭东西构造带，武都弧型构造(舟曲—成县—徽县区域断裂、岷县—宕昌—两当区域断裂、窑上—石峡断裂)	重要
	成矿时代	印支晚期(晚三叠纪)	必要
主攻矿种		金、锑	重要
成矿地质体		印支晚期中酸性侵入体(深部隐伏)	必要
脉体		中酸性岩脉、(黑云母)花岗闪长岩脉、长英岩脉和煌斑岩脉	次要
成矿构造及成矿结构面		层控–热液型金矿：成矿构造主要为NE向区域性构造及其发育的次级断裂、裂隙构造，呈不规则线状披覆于石炭系基底灰岩上的滑脱断层，总体呈NE—SW走向基底高角度断层。成矿结构面为细碎屑岩建造和碳酸盐岩建造之间的大型硅钙界面	必要
		构造–热液型锑矿：成矿构造主要为一套NEE—SWW的走向断层以及NE—SW向次级平行小断裂。成矿结构面是此类型成矿构造的次生构造成因成矿结构面	
		构造–热液型金矿：成矿构造主要为一套与NW向区域构造大致平行的层间挤压断裂破碎带、构造裂隙。成矿结构面是此类型成矿构造的次生构造成因成矿结构面	
成矿作用特征标志	矿床(点)	13个岩浆期后(中)低温热液型金矿床(点)，8个锑矿床(点)	必要
	蚀变类型	层控–热液型金矿：硅化、碳酸盐化、绢云母化、萤石化、黄铁矿化、褐铁矿化等，其中硅化与金矿化关系密切	重要
		构造–热液型金矿：硅化、碳酸盐化(脉状方解石)、迪开石化、滑石化及星点状黄铁矿化、臭葱石化、雄雌黄矿化等，其次还有绿泥石化、叶蜡石化、萤石化及绢云母化等	
		构造–热液型锑矿：硅化、方解石化、黄铁矿化和萤石化及少量的褐铁矿化、绢云母化、高岭土化。其中硅化与锑矿化关系密切	
	风化特征	构造–热液型金矿：褐铁矿化	次要
		构造–热液型锑矿：锑赭石化、褐铁矿化、高岭土化、黄锑华化	
矿物组合		层控–热液型金矿：金属矿物主要以黄铁矿、褐铁矿、白铁矿等为主，其次有毒砂、黄铜矿、闪锌矿、方铅矿等；脉石矿物主要有石英，少量方解石、白云石、长石、绢云母、绿泥石、高岭土、萤石、磷灰石、锆石等	重要
		构造–热液型金矿床：矿石矿物主要为黄铁矿、雌黄和雄黄，其次为毒砂、白铁矿、褐铁矿、汞砷黝铜矿、自然砷、自然硫、辉锑矿、锑汞矿、方铅矿、辰砂、闪锌矿、银黝铜矿、臭葱石、特硫锑铅矿等；脉石矿物主要有石英、迪开石、高岭石、白云母、绢云母、方解石、白云石等	
		构造–热液型锑矿床：金属矿物主要为辉锑矿、黄铁矿、白铁矿、锑赭石、黄锑华；非金属矿物主要有石英、方解石、萤石、绢云母、高岭土等	

素，补充根据区域物探、化探、遥感资料推断的隐伏岩体 (成矿地质体) 和构造 (成矿构造)；对与成矿无关的地层、岩浆岩等简要表达。同时，编图过程中使每个要素形成一个图层。

2.4.3 预测要素图

2.4.3.1 预测要素分析及区域预测模型的建立

成矿要素主要反映成矿的地质类信息，从成矿要素中提取出成矿作用形成的可识别的标志作为预测要素，利用地球物理、地球化学、遥感等手段，处理并筛选出与成矿有关的物探、化探、遥感预测要素，对地质类预测要素作以补充。其中，航磁、遥感解译成果指示成矿构造及隐伏岩体 (成矿地质体)，Au、Sb、As 等元素组合异常是该区热液型金、锑矿床地球化学异常的主要表现形式，同时，利用原生晕分带的理论，确定本区金、锑矿床前缘异常元素为 Hg、Sb、As，尾晕元素为 W、Mo、Bi，用以判定整装勘查区剥蚀程度，对矿床的定位有一定的指示意义。以此建立整装勘查区预测要素表 (表 5)。在预测要素分析的基础上，以成矿模式图为底图，叠加化探剖面，绘制区域预测模型图 (图 3)。

表 5 甘肃崖湾—大桥金锑整装勘查区区域预测要素表

成矿要素		描述内容	分类
成矿地质背景	大地构造位置	北部为白龙江隆起带沉积区，南部为阿尼玛卿裂陷沉积区	重要
	区域成矿带	北部为碌曲—徽县成矿亚带；南部为迭部—陇南成矿亚带	重要
	岩浆岩带	北部为白龙江隆起带构造岩浆岩段，南部为阿尼玛卿裂陷沉积区构造岩浆岩段	重要
	构造环境	秦岭东西构造带，武都弧型构造(舟曲—成县—徽县区域断裂、岷县—宕昌—两当区域断裂、窑上—石峡断裂)	重要
	成矿时代	印支晚期(晚三叠世)	必要
主攻矿种		金、锑	重要
成矿地质体		印支晚期中酸性侵入体(深部隐伏岩体)	必要
脉体		中酸性岩脉、(黑云母)花岗闪长岩脉、长英岩脉和煌斑岩脉	次要
成矿构造及成矿结构面		层控–热液型金矿：成矿构造主要为北东向区域性构造及其发育的次级断裂、裂隙构造，呈不规则线状披覆于石炭系基底灰岩上的滑脱断层，总体呈北东—南西走向基底高角度断层。成矿结构面为细碎屑岩建造和碳酸盐岩建造之间的大型硅钙界面 构造–热液型锑矿：成矿构造主要为一套NEE—SWW向的断层以及NE—SW向次级平行小断裂。成矿结构面是此类型成矿构造的次生构造成因成矿结构面 构造–热液型金矿：成矿构造主要为一套与NW向区域构造大致平行的层间挤压断裂破碎带、构造裂隙。成矿结构面是此类型成矿构造的次生构造成因成矿结构面	必要
成矿作用特征标志	矿床(点)	13个岩浆期后(中)低温热液型金矿床(点)，8个锑矿床(点)	必要
	蚀变类型	层控–热液型金矿：硅化、碳酸盐化、绢云母化、萤石化、黄铁矿化、褐铁矿化等 构造–热液型金矿：硅化、碳酸盐化(脉状方解石)、迪开石化、滑石化及星点状黄铁矿化、臭葱石化、雄雌黄矿化等 构造–热液型锑矿：硅化、方解石化、黄铁矿化和萤石化等。其中硅化与金、锑矿化关系密切	重要
	风化特征	构造–热液型金矿：褐铁矿化 构造–热液型锑矿：锑赭石化、褐铁矿化、高岭土化、黄锑华化	次要

续表 5

成矿要素		描述内容	分类
矿物组合		层控–热液型金矿：金属矿物主要以黄铁矿、褐铁矿、白铁矿等为主 构造–热液型金矿床：矿石矿物主要为黄铁矿、雌黄和雄黄 构造–热液型锑矿床：金属矿物主要为辉锑矿、黄铁矿、白铁矿、锑锗石、黄锑华	重要
物探	重力	利用重力资料推断解释出19条断裂构造，其中一级断裂1条，三级断裂18条，是间接找矿的重要要素	重要
		圈定侵入岩体6处(基性–超基性岩体1处，酸性–中酸性岩岩体5处)，其中酸性–中酸性岩体与金锑成矿有关	重要
		推断中—新生代沉积盆地5处	次要
	航磁	利用磁测资料推断解释出19条断裂构造，其中一级断裂1条，三级断裂18条，是间接找矿的重要要素	重要
		圈定侵入岩体6处(基性–超基性岩1处、酸性–中酸性岩5处)，其中酸性–中酸性岩体与金锑成矿有关	重要
		推断变质岩地层1处	次要
		依据磁异常特征及地质背景，筛选出磁异常24处，其中甲类异常7处、乙类异常5处、丙类异常1处，丁类异常11处	次要
化探	地球化学异常	Au、As、Hg、Sb、Cu、Pb、Zn、Ag、Cd、W、Bi、Mo、Sn13种元素综合异常，Au、As、Hg、Sb 单元素异常	必要
	化探推断	利用化探资料推断出2处岩体	重要
	剥蚀程度	通过WMoBi衬值积与HgAsSb衬值积做比值，分析出全区剥蚀程度： 层控–热液型金矿床：比值变化范围为1.169 8 ~ 12.919 2，属中等剥蚀程度 构造–热液型金矿床：比值变化范围为0.053 5 ~ 3.080 1，属弱剥蚀程度 构造–热液型锑矿床：比值变化范围为0.053 5 ~ 3.080 1，属弱剥蚀程度 剥蚀程度影响矿体是否被剥蚀	重要
遥感	线要素	NWW–EW–NEE向区域性断裂以及NE向和SN向次级断层，控制着工作区的构造格局，亦作为控岩控矿构造，与热液型矿床成因有密切关系	必要
	环要素	17处环形构造以单环形态为主，另有半环、同心环和相切环，多与隐伏岩体有关，部分与构造作用有关，与成矿关系不明	次要
	带要素	区内6组带状要素由灰岩、粉砂质板岩、硅质岩、砂岩等岩石组成，在区域上与成矿关系密切，具有较明确的示矿意义	重要
	遥感异常	铁染、铝羟基、镁羟基、碳酸盐、硅化等遥感异常强度较大、较集中，套合性、成带性较好，硅化、碳酸盐化异常零星分布在葱地东、两河口、铁夹山等一带，多处于三叠系河湖相碎屑岩、泥盆系浅海相碎屑岩等地层、岩层接触地带及区域性断裂影响部位。羟基、碳酸盐化等异常分布区域与已知矿点、矿化带或矿化蚀变有较好的对应或套合关系，遥感找矿预测标志较好	重要

2.4.3.2　预测要素图编制

以成矿要素图为底图，为体现物探、化探、遥感预测要素，删除沉积建造、侵入岩建造区图层，仅保留岩性花纹并淡化表达。叠加物探预测要素：解译的中酸性岩体、构造；化探要素：Au–Hg–As–Sb 组合异常及金、锑、砷单元素异常、解译的中酸性岩体；遥感解译的成矿构造。插入预测要素表图层及预测模型图图层。

2.4.4　预测成果图

区内典型矿床均为地质建造、变形构造、侵入岩浆作用综合因素时空定位的矿产，将矿产预测方法类型均划分为复合内生型。基于矿产预测 GIS 评价系统提取预测信息，

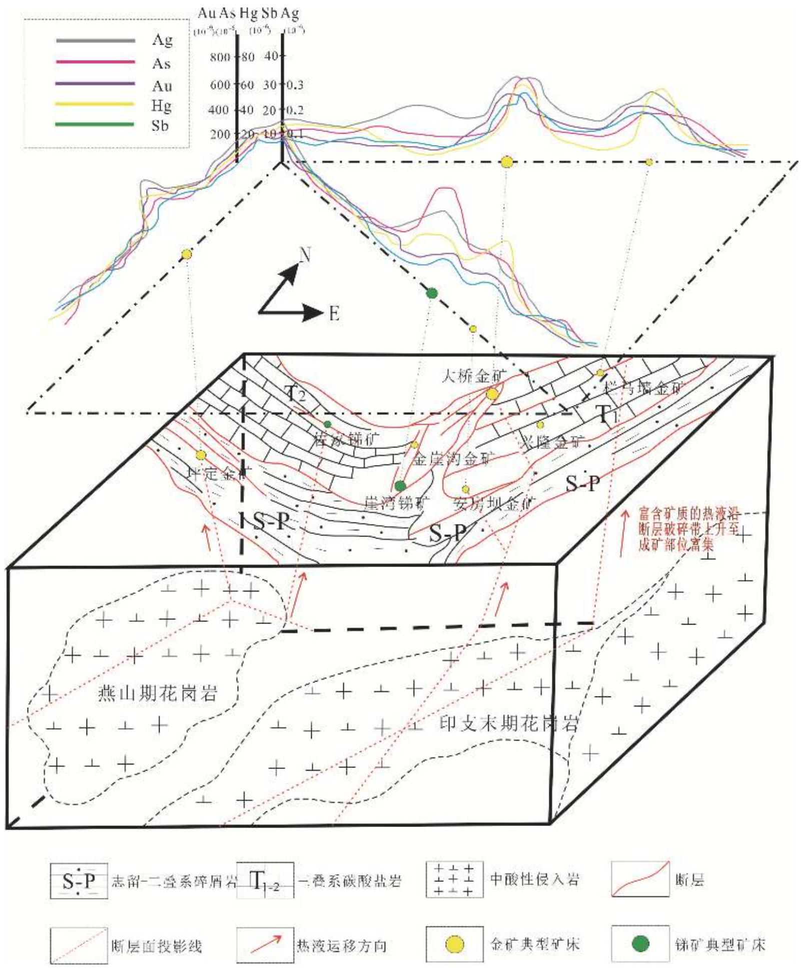

图 3　整装勘查区区域预测模型图

提取结果的表现形式为区文件，提取的信息包括：成矿构造 (根据不同预测类型成矿构造的产状、性质等分别提取，结合构造与矿点影响域频率，构建缓冲区)、成矿地质体 (解译的印支晚期—燕山期中酸性侵入体，结合构造与矿点影响域频率，构建缓冲区)、含矿建造、地球化学异常 (金、锑、砷单元素异常及金–汞–砷–锑组合异常) 等，根据所建立的预测评价模型，采用要素叠加法，应用 MRAS 软件交互搜索模型建模器，进行预测要素之间交、并等运算，最终圈定最小预测区，采用人工选择模型单元法确定成矿概率。本次工作以剥蚀程度作为优选要素，优化最小预测区，最终确定金、锑最小预测区 42 个，占整装勘查区总面积的 2.7%，进一步建立预测评价模型区，根据已查明资源量 (333 资源量以上)、矿脉聚集区面积、勘查最大深度等参数，计算预测深度、含矿地质体含矿系数等，采用含矿地质体体积法估算预测资源量。

在预测要素图的基础上，用横线填充 A 类最小预测区 (成矿条件十分有利，且矿床所在最小预测区)，竖线填充 B 类最小预测区 (成矿条件有利)，交叉线填充 C 类最小预测区 (成矿条件一般)，并标注编号、名称、面积、深度、相似系数、预测资源量类别、最小预测区类别等。最终，叠加各类预测表格图层。

2.5　数据集属性数据赋值

本次数据集属性赋值依据中国地质调查局《地质信息元数据标准》(DD2006–05)，

参照《数字地质图空间数据库建库标准》(DD2006–06)，数据库建库采用《矿产资源潜力评价数据模型方法技术体系》。按各类型图件及 GeoMAG 要求完成相应的数据库建设工作。

3 数据样本描述

对综合建造构造图、磁测类、化探类和遥感类图件、成矿要素图、预测要素图、预测成果图、成矿规律图、勘查工作部署建议图等属性数据赋值，并建立了相应的数据库。部分数据库单元在各图件中具有继承性，仅对各图件特有数据库单元进行说明。

建造构造图有以下单元：沉积岩建造的编号，特征代码，图元编号，沉积岩建造大类，岩石组合，填图单位名称，填图单位代号，第四系成因类型，形成时代，建造，含矿层厚度，主要化石组合，沉积相；侵入岩建造的编号，特征代码，图元编号，岩性代码，地理位置经度，地理位置纬度，填图单位名称，填图单位代号，形成时代，特殊岩石，矿物成分，岩石颜色，岩石结构，岩石构造，侵入岩产状，岩墙，包体特征，侵位深度，侵位方式，剥蚀程度，重要岩石化学参数，岩石系列，岩石成因类型，岩石构造组合，大地构造环境；断裂的编号，名称，长度，类型，断裂面倾向 (倾角)，断裂两侧及断裂带内岩石，构造层次，切割深度，运动方式，力学性质，形成时代，叠加运动；褶皱的编号，褶皱名称 (类型、形态、程度)，枢纽倾伏角，褶皱倾伏向，轴面倾向 (倾角)，卷入褶皱的地层，褶皱组合形式，褶皱成因，形成时代，叠加褶皱特征；产状的编号，产状类型，倾向，倾角，走向。

磁测类、化探类和遥感类图件主要单元：断裂编号，出露情况，断裂级别，断裂构造走向，断裂长度，断裂构造磁场标志，航磁 ΔT 等值线和航磁 ΔT 化极等值线中的等值线的编号、等值线值，等值线区的编号、起始值、终止值；单元素地球化学图中的等值线的编号，元素组分，含量值，等值线区的编号，元素组分，含量范围上限值，含量范围下限值；单元素地球化学异常图中地球化学异常边界线的异常编号，异常下限，地球化学异常范围面的编号，异常下限，极值点，异常编号，异常面积；地球化学异常图中综合异常范围的编号，面积，主要伴生元素，共生元素，主成矿元素范围的元素种类，异常下限，计量单位，异常面积。

成矿要素图数据库单元包括：矿产地的编号，特征代码，图元编号，名称，交通位置，地理经、纬度，赋矿岩石，控矿构造，主矿产，大地构造位置，成矿类型，主矿产规模，主矿产资源储量 (单位)，主矿产平均品位 (单位)，共、伴生矿产 (储量、单位)，成矿区带，成矿系列，矿床式，成矿时代，成矿年龄，年龄误差，测定方法，矿体空间组合类型，主矿体编号，主矿体形状 (规模、走向、倾向、倾角、长度、厚度)，矿石组分 (品位、矿物成分、结构、构造)，蚀变带长度 (宽度)，围岩蚀变组合，蚀变强度。

预测成果图有以下单元：最小预测区编号，名称，面积，比例尺，地理位置，成矿地质背景，矿产预测类型，预测区类别，已探明资源量，资源量估算方法；最小预测区储量数据表 (EXCEL)。

成矿规律图单元有：成矿区带，矿集区和成矿远景区界线编号，名称，代表矿床名称。

勘查工作部署建议图相应的数据库单元有：部署建议区编号，名称，等级，矿种，中大比例尺填图工作，勘查工作建议，预期成果，勘查工作部署建议表 (EXCEL)。

4 数据质量控制和评估

数据集是本次潜力评价成果的最终体现，项目的开展及数据集的建设收集了工作范围内前人丰富的数据资料，数据资料均真实可靠。仅两当幅，舟曲幅，沙湾幅以往未进行调查工作，因此采用 1∶250 000 岷县幅、天水幅、武都幅、略阳县幅区域地质调查资料，结合图切剖面进行综合建造构造图的编制；航磁数据由新收集 500 m × 500 m 网格数据集成处理；化探类数据由收集到的 1∶50 000 资料进行处理，上述资料严格按照 2018 年由自然资源部矿产勘查技术指导中心组织编制的《整装勘查区 1∶50 000 矿产资源潜力评价技术指南 (初稿)》要求执行，数据来源可靠，数据库建设严格按照《矿产资源潜力评价数据模型方法技术体系》(中国地质调查局发展研究中心, 2016) 规定执行，属性库建设完善。

在数据集制作过程中，严格执行质量三级检查制度，并受甘肃省地质调查院质量体系控制。2019 年 1 月上旬，中国地质调查局发展研究中心 (自然资源部矿产勘查技术指导中心) 组织专家评审了甘肃崖湾—大桥地区金锑矿整装勘查区 1∶50 000 矿产资源潜力评价专题研究报告及数据库，专家组一致通过评审，等级为优秀。

5 数据价值

(1) 以“三位一体”找矿预测理论为指导，梳理出大桥金矿、坪定金矿、崖湾锑矿的预测要素，建立了预测模型。

(2) 在西秦岭地区成矿规律研究的基础上，对整装勘查区成矿规律进行了研究，在全国 III 级成矿区带的基础上，根据全国潜力评价成果划分了 IV 级成矿区 2 个，V 级矿集区 6 个，根据本次矿产预测成果，划分了 V 级金锑成矿远景区 8 个。

(3) 在系统地收集和整理不同精度航磁资料的基础上，在整装勘查区利用 500 m × 500 m 网格数据，编制了整装勘查区 1∶50 000 航磁工作程度图、航磁 ΔT 等值线平面图、航磁 ΔT 化极等值线平面图、航磁 ΔT 化极垂向一阶导数等值线平面图，对解译岩体及构造做出了进一步的探索与数据更新，对预测工作起到了间接的指示作用。

(4) 集成整装勘查区各图幅 1∶50 000 地球化学数据，圈定了金等 15 种单元素异常 597 处、综合异常 59 处，解译出中酸性岩体 2 处。通过剥蚀程度研究成果，对本次预测起到了显著作用。

(5) 提交典型矿床深部及外围预测资源量，大桥金矿 190 419 kg，坪定金矿 7 492 kg，崖湾锑矿 99 568 t；圈定大桥式层控–热液型金矿最小预测区 17 个，提交金矿预测资源量 353 470.26 kg；圈定坪定式构造–热液型金矿最小预测区 10 个，提交金矿预测资源量 107 171.85 kg；圈定崖湾式构造–热液型锑矿最小预测区 15 个，提交锑矿预测资源量 587 889.43 t。

(6) 根据矿产预测工作，共部署了 12 个勘查区，其中 I 级勘查区 3 个，分别为查尔金—坪定勘查区、大桥勘查区、庙湾—牌儿坝勘查区；II 级勘查区 3 个，分别为龙坝勘查区、安房坝勘查区、南家山勘查区；6 个 III 级勘查区，具体部署了 15 个普查区、22 个预查区，共计 37 个次级勘查区，预获金资源量 460.67 t，锑资源量 587 900 t。

6 结论

(1) 甘肃省崖湾—大桥地区金锑矿整装勘查区 1∶50 000 矿产资源潜力评价项目是中国地质调查局新一轮整装勘查区矿产地质调查与找矿预测项目的潜力评价示范项目，积极探索创新了一系列整装勘查区潜力评价工作方法及系列图件编制的方法，并建立潜力

评价数据集，对全国整装勘查区 1：50 000 潜力评价工作内容、工作流程、数据集的建立等起到了示范作用。

(2) 本次工作利用区内以往研究成果开展潜力评价工作，对前人成果和数据进行了梳理和整合。因此，本数据集的建立对数据的整理和集成具有重要意义。

(3) 利用整装勘查区内最新基础地质资料和科研资料，开展了整装勘查区沉积岩、侵入岩综合研究，编制整装勘查区综合建造构造图 (1：50 000)，为成矿规律研究和矿产预测提供了成矿地质背景基础资料，总结了切实可行的工作程序，提高了整装勘查区基础地质研究程度。依据此项目建立的数据集为该地区后续工作的开展提供了基础数据。

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注释：

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Dataset of 1∶50 000 Mineral Resource Potential Assessment of Gold–Antimony Deposit Integrated Exploration Area in Yawan–Daqiao Area, Gansu Province

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Abstract: The dataset of 1∶50 000 mineral resource potential assessment of the gold-antimony deposit integrated exploration area in Yawan−Daqiao Area, Gansu Province (also referred to as the Dataset) includes comprehensive suite-structure maps, metallogenic factor maps, predictive factor maps, prediction result maps, among others. During the development of the Dataset, the suites and structures in the integrated exploration area were collated using the latest data. Meanwhile, focusing on gold and antimony deposits, the Daqiao gold deposit, Pingding gold deposit, and Yawan antimony deposit in the integrated exploration area were studied based on the "trinity" prospecting prediction theory of exploration areas that integrates metallogenic geological bodies, metallogenic structures, metallogenic structural planes, and metallogenic characteristics and indicators. As a result, the genetic types and predication types were classified, the regional metallogenic regularity was summarized, and the regional predication models were established. Furthermore, 42 predicted minimum prospecting target areas were delineated, with predicted gold and antimony resources of 560 774.59 kg and 737 241.43 tonnes, respectively. The development of the Dataset provides a demonstration of 1∶50 000 mineral resource potential assessment of integrated exploration areas. Meanwhile, relevant research ideas, working methods and processes, expected results, and result presentence were summarized and explored. Therefore, this Dataset will provide certain references for similar potential assessment.

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Key words: potential assessment; trinity; gold deposit; antimony deposit; predicted resources; Dataset; 1：50 000; Yawan−Daqiao integrated exploration area; Gansu Province

Data service system URL: http://dcc.cgs.gov.cn

1 Introduction

The former Ministry of Land and Resources of the People's Republic of China proposed establishing relevant mechanisms to promote public-spirited geological work in the *Guidelines of 358 National Geological Prospecting Action*. To formulate national mineral resource plan, the China Geological Survey comprehensively figured out the mineral resources in integrated exploration areas through resource potential assessment. The purpose is to guide mineral geological surveys and mineral exploration, and to provide basic data and scientific bases for the planning, conservation, and utilization of national mineral resources and ecological civilization construction. The gold-antimony deposit integrated exploration area in Yawan−Daqiao area, Gansu Province (also referred to as the Yawan–Daqiao integrated exploration area) is a major concentration area of gold deposits in the West Qinling area and an important part of the Shanxi−Gansu−Sichuan Gold Triangle mineral area in China. This area has become a key region for prospecting breakthroughs of gold and antimony deposits in China in recent years owing to the special metallogenic environment. Furthermore, significant prospecting results have been obtained with the improvement in the understanding of its metallogenic characteristics. However, some new geological problems have gradually emerged when the prospecting in the integrated exploration area was transformed from deposit periphery to the whole area and deep strata. This has affected the deployment of mineral exploration. Therefore, a demonstration project for potential assessment of mineral resources in integrated exploration areas was set up in Yawan–Daqiao area, Gansu Province to carry out mineral prospection, delineate prospecting target areas, and assess resource potential. Meanwhile, it also aims to put forward suggestions on further prospecting deployment and develop a dataset of primary data and results.

The Yawan–Daqiao integrated exploration area lies in eastern part of the Bailongjiang uplift zone and Animaqen rift sedimentary zone of Qinling−Dabie Neoproterozoic−Paleozoic orogen (Fig. 1)[❶]. Two faults run through this area, namely Minxian−Tanchang−Liangdang deep fault and Zhouqu−Chengxian−Huixian regional fault, which separate the Xiahe−Lixian, Luqu−Chengxian, and Diebu−Wudu thrust nappe tectonic zones from north to south. As a result, the faults and thrust nappe zones are distributed in an arc shape along Wudu−Tianshui area, with the arc top facing southwards (Fig. 2; Zhao YQ, 2004). The integrated exploration area stretches across the axis of the arc-shaped structural belt from west to east. According to the study on the control of the arc-shaped structural belt over the gold deposits in west Qinling area, it can be argued that the gold deposits in the integrated exploration area are strongly controlled by the arc-shaped structural belt (Yin XM, 2009).

The Yawan–Daqiao integrated exploration area has the relatively developed sedimentary suite systems of marine-continental facies, which are dominated by the marine-facies flysch

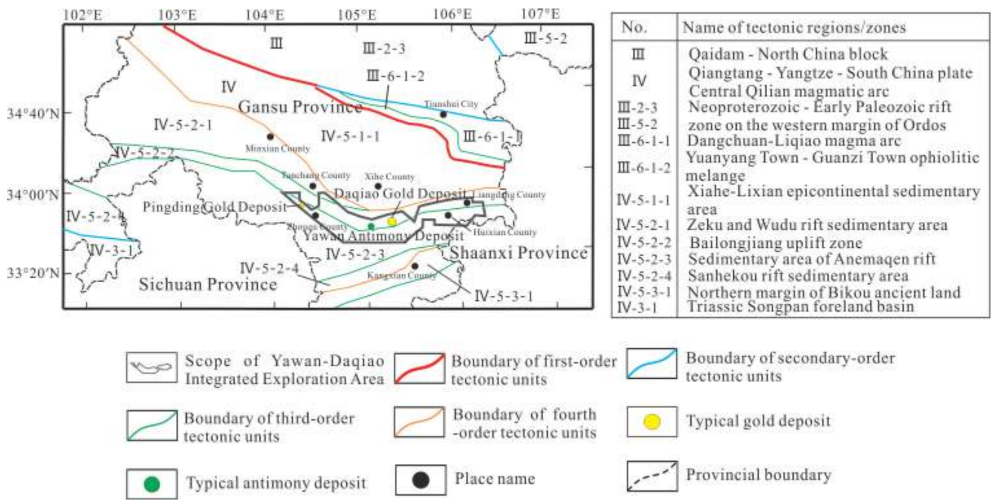

Fig. 1 Geotectonic location of Yawan–Daqiao integrated exploration area (modified from *Annals of Regional Geology in Gansu Province*, 2016❶)

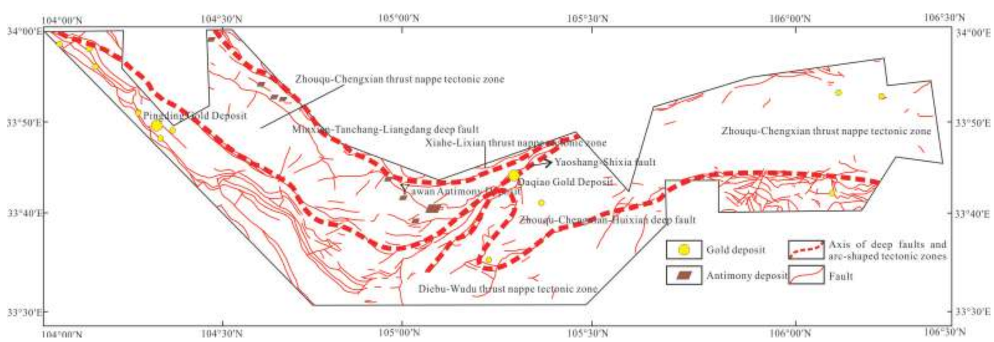

Fig. 2 Structure and mineral distribution of Yawan–Daqiao integrated exploration area

sedimentary suites. Triassic strata spread over the northern part of the integrated exploration area in the EW-NWW trending as a flysch suite in general, with the lithologic associations consisting of clastic rocks → sandstone, siltstone, and marl → phyllite, slate, and carbonate rock → marl, limestone, and dolomite. They serve as important ore-bearing strata of strata-bound–hydrothermal gold deposits. Paleozoic strata are developed in the southern part of the integrated exploration area as a sedimentary suite, which consists of marine-facies flysch clastic rocks, carbonate rocks, and siliceous rocks that have undergone low-grade metamorphism of lower greenschist facies. Cretaceous, Paleogene, and Neogene strata are scattered in the continental fault basins that are mainly in NE trending as a red molasse sedimentary suite. (Du YS, 1997)

According to the observation of the ground surface, magmatic rocks are sparsely exposed in the integrated exploration area. However, a large number of concealed intrusions were inferred from geochemical and geophysical exploration in this study. It is worthwhile to mention that a series of nearly parallel NNE-trending deep faults are believed to exist in the Tanchang–Tongwei–Jingning–Lixian area according to the deep seismic sounding results (Li QH, 1991) collected. These faults provide good pathways for magma intrusion and thus may prove the existence of structurally controlled magmatic rock belt in the area. The magmatic rocks most closely related to metallogenesis are intermediate-acid intrusive bodies, which mainly include Indosinian–Yanshanian plutons (Zhang X et al., 2017).

The minerals in the integrated exploration area mainly include gold and antimony, and the deposits discovered in the area are regularly distributed in a banded pattern. Among them, the major deposits include super-large Daqiao gold deposit, large Yawan antimony deposit, and medium-sized Pingding gold deposit. In addition, small-sized deposits in the area include Yangliweigou gold deposit, Shuiyantou antimony deposit, and Anfangba gold deposit. All these gold and antimony deposits lie on the margin of NE- or NW-trending uplifts or on the sides of regional faults.

The metadata table of the Dataset (Zhang JR et al., 2020) is shown in Table 1.

Table 1　Metadata Table of Database (Dataset)

Item	Description
Database (dataset) name	Dataset of 1：50 000 Mineral Resource Potential Assessment of Gold–Antimony Deposit Integrated Exploration Area in Yawan–Daqiao Area, Gansu Province
Database (dataset) authors	Zhang Jiarui, Gansu Institute of Geological Survey, responsible for the organization and implementation of the project and the establishment of the Dataset Su Hu, Gansu Institute of Geological Survey, responsible for the development of the development of remote sensing dataset Yu Xianglong, Gansu Institute of Geological Survey, responsible for the development of geological dataset Gao Yongwei, Gansu Institute of Geological Survey, responsible for the development of mineral dataset Jiang Wen, Gansu Institute of Geological Survey, responsible for the development of geophysical dataset Liu Yuanping, Gansu Institute of Geological Survey, responsible for the development of geochemical dataset Li Zeng, Gansu Institute of Geological Survey, responsible for the development of geological dataset Li Yongsheng, Development and Research Center of China Geological Survey (i.e., Technical Guidance Center for Mineral Resources of Ministry of Natural Resources), responsible for the development of mineral dataset
Data acquisition time	2018–2019
Geographical area	West Qinling area, 104°00′–106°29′E, 33°30′–34°00′N
Data format	*.wl, *.wt, *.wp, *.docx
Data size	1.2 GB
Data service system URL	http://dcc.cgs.gov.cn
Fund project	The geological survey subproject entitled 1：50 000 *Mineral Resource Potential Assessment of Gold-Antimony Deposit Integrated Exploration Area in Yawan–Daqiao Area, Gansu Province* (No.: 0747-1861 SITCN150-66)
Language	Chinese
Database (dataset) composition	The Dataset mainly consists of comprehensive suite-structure maps, metallogenic factor maps, predicative factor maps, prediction result maps, metallogenic regularity maps, and exploration deployment suggestion maps in MapGIS format.

2 Methods for Data Acquisition and Processing

2.1 Data Bases

A series of 1∶50 000 mineral resource potential assessment maps of the Yawan–Daqiao integrated exploration area were prepared under the guidance of the afore-mentioned "trinity" prospecting predication theory according to the *Technical Guidelines for* 1∶50 000 *Mineral Resource Potential Assessment of Integrated Exploration Areas* (*Draft*) developed by the Exploration Technical Guidance Center of the Ministry of Natural Resources of the People's Republic of China in 2018. They were developed based on the primary data obtained from the national mineral resource potential assessment, mineral geological surveys, mineral prospect surveys, and regional geological surveys of the area. The coordinate systems adopted include the Beijing Geodetic Coordinate System 1954, National Height Datum 1985, and National Geodetic Coordinate System 2000 (CGCS2000). Data processing and map compilation were performed using the software such as Digital Geological Survey System (DGSS) and MapGIS, with the mapping scale of 1∶50 000.

2.2 Data Acquisition

The Yawan–Daqiao integrated exploration area involves twenty-two 1∶50 000 standard map sheets, covering an area of about 5 613.84 km^2. The data collected mainly include the results and primary data obtained from 1∶50 000 mineral geological surveys, mineral prospect surveys, and regional geological surveys[❶–❽]. They were supplemented with 1∶100 000 or 1∶250 000 survey data and were timely updated during the building of the Dataset. In addition, 18 209 pieces of primary geochemical data were used, including 17 831 pieces obtained from 1∶50 000 geochemical exploration and 378 pieces from 1∶200 000 geochemical exploration.

Based on these data, a series of suite-structure maps, metallogenic factor maps, predictive factor maps, prediction result maps, metallogenic regularity maps, and exploration deployment suggestion maps were compiled.

2.3 Processing Methods of Geophysical and Geochemical Data

2.3.1 Processing of 1∶50 000 Aeromagnetic Data

Previous aeromagnetic data of the Yawan–Daqiao integrated exploration area mostly have a grid cell size of 2 km × 2 km. However, in this study, the aeromagnetic data with a grid cell size of 500 m ×500 m issued by the Shijiazhuang Nuclear Industry Aeromagnetic Survey and Remote Sensing Center in 2015‒2017 was collected. Therefore, it is necessary to sort out and integrate the 1∶50 000 aeromagnetic data of the integrated exploration area. The details are as follows:

First, perform leveling and splicing of aeromagnetic data in different formats and form the grid data with a cell size of 500 m×500 m using the Kriging method. Second, conduct potential field transformations on the gridded data using the software GeoIPAS 4.0, including varying latitude-based reduction to the pole (RTP) by blocks, RTP-based vertical first derivative, and analytic continuation. As a result, a series of aeromagnetic maps can be obtained, such as the aeromagnetic (ΔT) anomaly maps, aeromagnetic (ΔT) RTP plans, aeromagnetic (ΔT) RTP-based vertical first-order derivative maps, and aeromagnetic (ΔT) residual RTP anomaly maps. Finally, summarize the regional ore-controlling geological−geophysical indicators and determine prospect areas according to basic geological, geochemical, and remote-sensing data along with the comparison between the plane characteristics of the magnetic field and the distribution of known deposits.

2.3.2 Processing of 1∶50 000 Geochemical Data

The 1∶50 000 geochemical data were collected from 18 209 data points in this study. After check and correction of primary data, the concentration coefficient (*K*k) and the coefficient of variation (*C*v) were calculated. Based on these parameters as well as the geological and mineral background of the Yawan–Daqiao integrated exploration area, it can be determined that the elements including Au, Sb, As, Hg, and Bi have great metallogenic potentiality and thus are major metallogenic elements in the area.

The anomaly thresholds (T) was determined using mathematical statistics according to the formula T=X+2S, where X and S are the mean and standard deviation of the geochemical background field. The results are listed in Table 2.

A total of 597 single-element anomalies of 15 elements such as Ag, As, and Au and 59 integrated anomalies were delineated in this study. The integrated anomalies consist of nine Class A anomalies (four Class A_1 and five Class A_2 anomalies), 21 Class B anomalies (three Class B_2 and 18 Class B_3 anomalies), 29 Class C anomalies (seven Class C_1, seven Class C_2, and 15 Class

Table 2 Calculation results of anomaly thresholds

Element	Sample quantity	After removing extra-high and extra-low values (geochemical background field)			Anomaly threshold
		Sample quantity	Mean (X)	Deviation (S)	
Cu	18 209	16 673	26.781 8	8.829 3	44.44
Pb	18 209	17 085	28.393 6	7.486 5	43.37
Zn	18 209	16 172	93.458	27.211 9	147.9
Ag	18 209	16 570	91.773 9	41.266	174.3
Mo	18 209	16 297	1.139 9	0.597 1	2.334
Sn	18 209	17 218	3.437 2	0.900 4	5.24
W	18 209	17 347	2.393 9	1.026 9	4.45
Mn	17 615	16 665	707.971	214.262 3	1 136.5
Ba	16 971	16 004	483.452 8	132.901 6	749.3
As	18 209	16 872	13.642 5	8.391 6	30.43
Sb	18 209	16 346	1.641 8	1.145 3	3.93
Bi	18 209	16 372	0.329 5	0.083 5	0.497
Cd	16 282	14 956	0.251 6	0.129 7	0.51
Au	18 209	16 534	1.288 7	0.773 6	2.836
Hg	18 209	17 537	108.811 5	144.721 3	398.3

Note: The dimension is 10^{-9} for Au, Ag, and Hg and 10^{-6} for other elements.

C_3 anomalies). An analytical map and a registration card were prepared for each integrated anomaly. Moreover, two concealed plutons were inferred from composite anomaly maps.

2.3.3 Processing of Remote Sensing Data

In this study, the remote sensing data were newly collected from the satellites Gaofen-1 and Gaofen-2. Compared with previous ETM data, they are newer and have higher precision. To highlight the effective information in the remote sensing images, true-color synthetic images and standard false-color remote sensing images on the same scale as the base map of the integrated exploration area were developed based on combination of different wavebands as well as image enhancement, fusion, and spatial filtering.

2.4 Methods for Preparation of Major Maps

2.4.1 Comprehensive Suite-tectonic Maps

Firstly, the latest mineral geological maps collected were preliminarily spliced. Secondly, based on existing cross-sections of the area and the research results of typical deposits such as Daqiao gold deposit, Yawan antimony deposit, and Pingding gold deposit, the sedimentary rock suites and intrusive rock suites in the integrated exploration area were systematically determined through data analysis and selection. Thirdly, geological boundaries were verified and corrected, and lithological patterns were filled in according to the characteristics of the lithologic associations and occurrence. In this way, the comprehensive suite-structure maps were formed. To ensure the reliability of mineral predication, section lines running across typical mineral deposits and perpendicular to the stratigraphic strike were selected to prepare the maps. According to the analysis and collation of the suites and structures of typical mineral deposits and regional suites and structures, the ore-bearing suites of the Daqiao gold deposit, Yawan antimony deposit, and Pingding gold deposit were determined to be thin-laminated carbonaceous-silty limestone suite of the Triassic Huashiguan Formation, the limestone suite of the Triassic Daheba Formation, and the suite of the Devonian Xiawuna Formation consisting of carbonate interbedded with sandstone, respectively.

2.4.2 Metallogenic Factor Maps

2.4.2.1 Division of Predicted Mineral Types

The main types of prospecting deposits in the Yawan–Daqiao integrated exploration area were determined to be gold and antimony deposits according to the study on regional metallogenic regularity and typical deposits in the area. The details are shown in Table 3.

2.4.2.2 Analysis of Metallogenic Factors and Establishment of Metallogenic Model Maps

The research data on typical mineral deposits (i.e., the Daqiao gold deposit, Yawan antimony deposit, and Pingding gold deposit) and other deposits (ore occurrences) in the Yawan–Daqiao integrated exploration area were completely collected. Based on this, the metallogenic geologic blocks, metallogenic structures, metallogenic structural planes, and metallogenic characteristics and indicators of three types of typical deposits in the area were analyzed and collated following the “trinity” prospecting prediction theory for exploration areas proposed by researcher Ye Tianzhu (Ye TZ et al., 2014, 2017). Meanwhile, deep faults strictly control the distribution of suites in the area, and the distribution of the deposits is

Table 3 Classification of mineral types to be predicted in Yawan–Daqiao gold-antimony deposit integrated exploration area in Gansu Province

Second-level classification	Third-level classification	Genetic type	Mineral type to be predicted
Magmatic deposits	Postmagmatic (medium-) low-temperature hydrothermal deposits	Stratabound−hydrothermal type	Daqiao-type stratabound−hydrothermal gold deposit
		Structural−hydrothermal type	Pingding-type structural−hydrothermal gold deposit
			Yawan-type structural−hydrothermal antimony deposit

closely related to the suites. Therefore, deep faults play a significant role in controlling the diagenesis and mineralization in the area and thus affect the formation and temporal and spatial distribution of various endogenous deposits in the area.

Based on this, the metallogenic factor table (Table 4) and regional metallogenic model maps of the integrated exploration area were established.

2.4.2.3 Preparation of Metallogenic Factor Maps

The metallogenic factor maps were prepared based on the analysis of the metallogenic factors, with comprehensive suite-structure maps serving as the base map. On these maps, necessary and major metallogenic factors were retained, concealed plutons (metallogenic geologic blocks) and structures (metallogenic structures) inferred from regional geophysical, geochemical, and remote-sensing data were supplemented, and the strata and magmatic rocks unrelated to mineralization are simply expressed. Moreover, a map layer was established for each metallogenic factor during mapping.

2.4.3 Predictive Factor Maps

2.4.3.1 Analysis of Predictive Factors and Establishment of Regional Prediction Models

The metallogenic factors mainly reflect the geological information related to metallogenesis, from which the identifiable indicators formed from metallogenesis were extracted as predictive factors. Meanwhile, geological predictive factors were supplemented with geophysical, geochemical, and remote-sensing predictive factors determined by geophysical exploration, geochemical exploration, and remote sensing. Among them, the aeromagnetic and remote-sensing interpretation results indicated metallogenic structures and concealed plutons (metallogenic geologic blocks). They also indicated that geochemical anomalies of hydrothermal gold-antimony deposits in the area mainly include the composite anomalies of the elements such as Au, Sb, and As. Meanwhile, according to the theory of primary halo zoning, the anomalous front halo elements of the gold-antimony deposits in the area include Hg, Sb, and As, and anomalous tail halo elements include W, Mo, and Bi. They are used to determine the denudation degree of the area and indicate the locations of mineral deposits to some extent. In this way, the predictive factor data table of the area was established (Table 5). Based on the analysis of predictive factors, the regional prediction model figure was prepared by superimposing geochemical profiles on the base map of the metallogenic model map (Fig. 3).

Table 4 Metallogenic factors of the Yawan−Daqiao gold-antimony deposit integrated exploration area in Gansu Province

Metallogenic factor		Description	Type
Metallogenic geological setting	Geotectonic location	The northern part is the sedimentary area of Bailongjiang uplift belt and the southern part is the sedimentary area of Anemaqen rift.	Major
	Regional metallogenic belt	The northern part is the Luqu−Huixian metallogenic subzone, and the southern part is the Diebu−Longnan metallogenic subzone.	Major
	Magmatic rock belt	The northern part is the tectono-magmatic rock section of the Bailongjiang uplift belt, and the southern part is the tectono-magmatic rock section of the sedimentary area of Anemaqen rift.	Major
	Tectonic environment	EW-trending Qinling tectonic belt, and Wudu arc-shaped structure (Zhouqu−Chengxian−Huixian regional fault, Minxian−Tanchang−Liangdang regional fault, and Yaoshang−Shixia fault)	Major
	Metallogenic epoch	Late Indosinian (Late Triassic)	Necessary
Major prospecting mineral types		Gold, antimony	Major
Metallogenic geologic blocks		Late Indosinian intermediate-acid intrusive bodies (deep concealed rock bodies)	Necessary
Vein bodies		Intermediate-acid dikes, (biotite) granodiorite dikes, quartzofeldspathic dikes, and lamprophyre dikes	Minor
Metallogenic structures and metallogenic structural planes		For stratabound−hydrothermal gold deposits, the metallogenic structures mainly include a NE-trending regional structure and its secondary faults and fissure structures. They are detachment faults irregularly covering the basement consisting of Carboniferous limestone, and serve as basement fault in NE-SW strike with a high dip angle in general. The metallogenic structural plane of the deposits is a large siliceous−calcareous interface between a fine-grained clastic rock suite and a carbonate rock suite. For structural-hydrothermal antimony deposits, the metallogenic structures mainly include a set of NEE-SWW-trending faults and NE-SW-trending secondary parallel minor faults. The metallogenic structural plane is formed from the secondary structures of the metallogenic structures. For structural-hydrothermal gold deposits, the metallogenic structures mainly include a set of interlayer compressive fractured zones and structural fissures that are roughly parallel to the NW-trending regional structure. The metallogenic structural plane is formed from the secondary structures of the metallogenic structures.	Necessary

Continued table 4

Metallogenic factor		Description	Type
Characteristics and indicators of metallogenesis	Mineral deposit (ore occurrence)	Thirteen postmagmatic (medium-) low-temperature hydrothermal gold deposits (ore occurrences), and eight antimony deposits (ore occurrences)	Necessary
	Alteration types	For stratabound−hydrothermal gold deposits: silicification, carbonation, sericitization, fluoritization, pyritization, and ferritization; among them, the silicification is closely related to gold mineralization.	Major
		For structural−hydrothermal gold deposits: silicification, carbonation (veined calcite), dickitization, talcization, spotted pyritization, scoroditization, and mineralization of realgar and orpiment, followed by chloritization, pyrophyllization, fluoritization, and sericitization.	
		For structural-hydrothermal antimony deposits: silicification, calcitization, pyritization, fluoritization, and a small amount of limonitization, sericitization, and kaolinization. Among them, silicification is closely related to antimony mineralization.	
	Weathering characteristics	For structural-hydrothermal gold deposits: limonitization.	Minor
		For structural-hydrothermal antimony deposits: antimony-bearing germanitization, limonitization, kaolinization, and cervanitization.	
Mineral assemblages		For stratabound-hydrothermal gold deposits: the metal minerals are dominated by pyrite, limonite, and marcasite, followed by arsenopyrite, chalcopyrite, sphalerite, and galena; gangue minerals mainly include quartz and a small amount of calcite, dolomite, feldspar, sericite, chlorite, kaolin, fluorite, apatite, and zircon.	Major
		For structural-hydrothermal gold deposits: the ore minerals mainly include pyrite, orpiment, and realgar, followed by arsenopyrite, marcasite, limonite, mercury-bearing tennantite, native arsenic, native sulfur, antimonite, ammislite, galena, cinnabar, sphalerite, freibergite, scorodite, and special embritite; gangue minerals mainly include quartz, dickite, kaolinite, muscovite, sericite, calcite, and dolomite.	
		For structural-hydrothermal antimony deposits: the metal minerals mainly include antimonite, pyrite, marcasite, antimony-bearing germanite, and cervanite; non-metal minerals mainly include quartz, calcite, fluorite, sericite, and kaolin.	

Table 5 Regional predictive factors of the Yawan–Daqiao gold-antimony deposit integrated exploration area in Gansu Province

Metallogenic factor		Description	Type
Geological setting of metallogenesis	Geotectonic position	The northern part is the sedimentary area of Bailongjiang uplift belt and the southern part is the sedimentary area of Anemaqen rift.	Major
	Regional metallogenic belt	The north part is the Luqu−Huixian metallogenic subzone, and the southern part is the Diebu−Longnan metallogenic subzone.	Major
	Magmatic rock belt	The northern part is the tectono-magmatic rock section of the Bailongjiang uplift belt, and the southern part is the tectono-magmatic rock section of the sedimentary area of Anemaqen rift.	Major
	Tectonic environment	EW-trending Qinling tectonic belt, and Wudu arc-shaped structure (Zhouqu−Chengxian−Huixian regional fault, Minxian−Tanchang−Liangdang regional fault, and Yaoshang−Shixia fault).	Major
	Metallogenic epoch	Late Indosinian (Late Triassic).	Necessary
Major prospecting mineral types		Gold, antimony	Major
Metallogenic geologic blocks		Late Indosinian intermediate-acid intrusive bodies (deep concealed rock bodies)	Necessary
Vein bodies		Intermediate-acid dikes, (biotite) granodiorite dikes, quartzofeldspathic dikes, and lamprophyre dikes	Necessary
Metallogenic structures and metallogenic structural planes		For stratabound−hydrothermal gold deposits, the metallogenic structures mainly include a NE-trending regional structure and its secondary faults and fissure structures. They are detachment faults irregularly covering the basement consisting of Carboniferous limestone, and serve as basement fault in NE-SW strike with a high dip angle in general. The metallogenic structural plane of the deposits is a large siliceous−calcareous interface between a fine-grained clastic rock suite and a carbonate rock suite.For structural-hydrothermal antimony deposits, the metallogenic structures mainly include a set of NEE-SWW-trending faults and NE-SW-trending secondary parallel minor faults. The metallogenic structural plane is formed from the secondary structures of the metallogenic structures.For structural-hydrothermal gold deposits, the metallogenic structures mainly include a set of interlayer compressive fractured zones and structural fissures that are roughly parallel to the NW-trending regional structure. The metallogenic structural plane is formed from the secondary structures of the metallogenic structures.	Necessary

Continued table 5

Metallogenic factor		Description	Type
Characteristics and indicators of metallogenesis	Mineral deposits (ore occurrence)	Thirteen postmagmatic (medium-) low-temperature hydrothermal gold deposits (ore occurrences), eight antimony deposits (ore occurrences)	Necessary
	Alteration types	For stratabound−hydrothermal gold deposits: silicification, carbonation, sericitization, fluoritization, pyritization, and ferritization.For structural−hydrothermal gold deposits: silicification, carbonation (veined calcite), dickitization, talcization, spotted pyritization, scoroditization, and mineralization of realgar and orpiment.For structural-hydrothermal antimony deposit: silicification, calcitization, pyritization, and fluoritization. Among them, silicification is closely related to mineralization of gold and antimony.	Major
	Weathering characteristics	For structural-hydrothermal gold deposits: limonitization.For structural-hydrothermal antimony deposits: antimony-bearing germanitization, limonitization, kaolinization, and cervanitization.	Minor
Mineral assemblages		For stratabound-hydrothermal gold deposits: the metal minerals are dominated by pyrite, limonite, and marcasite.For structural-hydrothermal gold deposits: the ore minerals mainly include pyrite, orpiment, and realgar.For structural-hydrothermal antimony deposits: the metal minerals mainly include antimonite, pyrite, marcasite, antimony-bearing germanite, and cervanite.	Major
Geophysical exploration	Gravity	19 fault structures were inferred from gravity data, including one first-order fault and 18 third-order faults. They are important factors for indirect prospecting.	Major
		Six intrusive plutons (one basic-ultrabasic intrusions, and five acid − intermediate-acid intrusions) were delineated, of which the acid − intermediate-acid intrusions are related to the metallogenesis of gold and antimony.	Major
		Five Mesozoic-Cenozoic sedimentary basins were inferred.	Minor
	Aeromagnetic survey	19 fault structures were inferred from aeromagnetic data, including one first-order fault and 18 third- order faults. They are important factors for indirect prospecting.	Major
		Six intrusive rocks (one basic-ultrabasic intrusions and five acid − intermediate-acid intrusions) were delineated, of which the acid − intermediate-acid intrusions are related to the metallogenesis of gold and antimony.	Major
		One metamorphic rock stratum was inferred.	Minor
		24 magnetic anomalies were screened out according to the characteristics of magnetic anomalies and geological setting, including seven Class A, five Class B, one Class C, and 11 Class D anomalies.	Minor

Continued table 5

Metallogenic factor		Description	Type
Chemical exploration	Geochemical anomalies	Integrated anomalies of thirteen elements, i.e., Au, As, Hg, Sb, Cu, Pb, Zn, Ag, Cd, W, Bi, Mo, and Sn, and single element anomalies of As, Hg, and Au.	Necessary
	Geochemical inference	Two plutons were inferred from geochemical data.	Major
	Denudation degree	The denudation degree of the whole area was analyzed based on the ratio of the contrast value product of W-Mo-Bi to the contrast value product of Hg-As-Sb.For stratabound-hydrothermal gold deposits: the ratio varies from 1.169 8 to 12.919 2, indicating medium denudation.For structure-hydrothermal gold deposits: the ratio varies from 0.053 5 to 3.080 1, indicating weak denudation.For structure-hydrothermal antimony deposits: the ratio varies from 0.053 5 to 3.080 1, indicating weak denudation.The denudation degree affects the denudation of ore bodies.	Major
Remote sensing	Line features	NWW–EW–NEE-trending regional faults and their NE- and SN-trending secondary faults control the tectonic framework of the integrated exploration area. They also serve as rock-controlling and ore-controlling structures, and are closely related to the genesis of hydrothermal deposits.	Necessary
	Circular features	A total of 17 circular structures were delineated. They are mainly single circular in shape, followed by semicircular, concentric circular, and tangent circular structures. Most of them are related to concealed plutons, and some of them are related to tectonism. However, their relationship with mineralization remains unclear.	Minor
	Zone features	There are six sets of zone features composed of limestone, silty slate, siliceous rock, and sandstone in the area. They are closely related to regional mineralization, thus having clear significance for mineralization indication.	Major
	Remote sensing anomalies	The remote sensing anomalies of iron staining, hydroxy aluminum, hydroxy magnesium, carbonatation, and silicification are relatively strong and concentrated. They overlap each other and form definite zones. The anomalies of silicification and carbonation are sparsely distributed in Congdidong, Lianghekou, and Tiejiashan areas. Most of them occur in the contact zones of the strata and rock formations such as Triassic clastic rocks of fluviatile-lacustrine facies, Devonian clastic rocks of neritic facies and the parts affected by regional faults. The regional distribution of the anomalies of hydroxyl and carbonation well overlaps with or corresponds to the known ore occurrences, mineralized zones, or mineralized alteration. Therefore, these anomalies serve as good predictive indicators for remote sensing prospecting.	Major

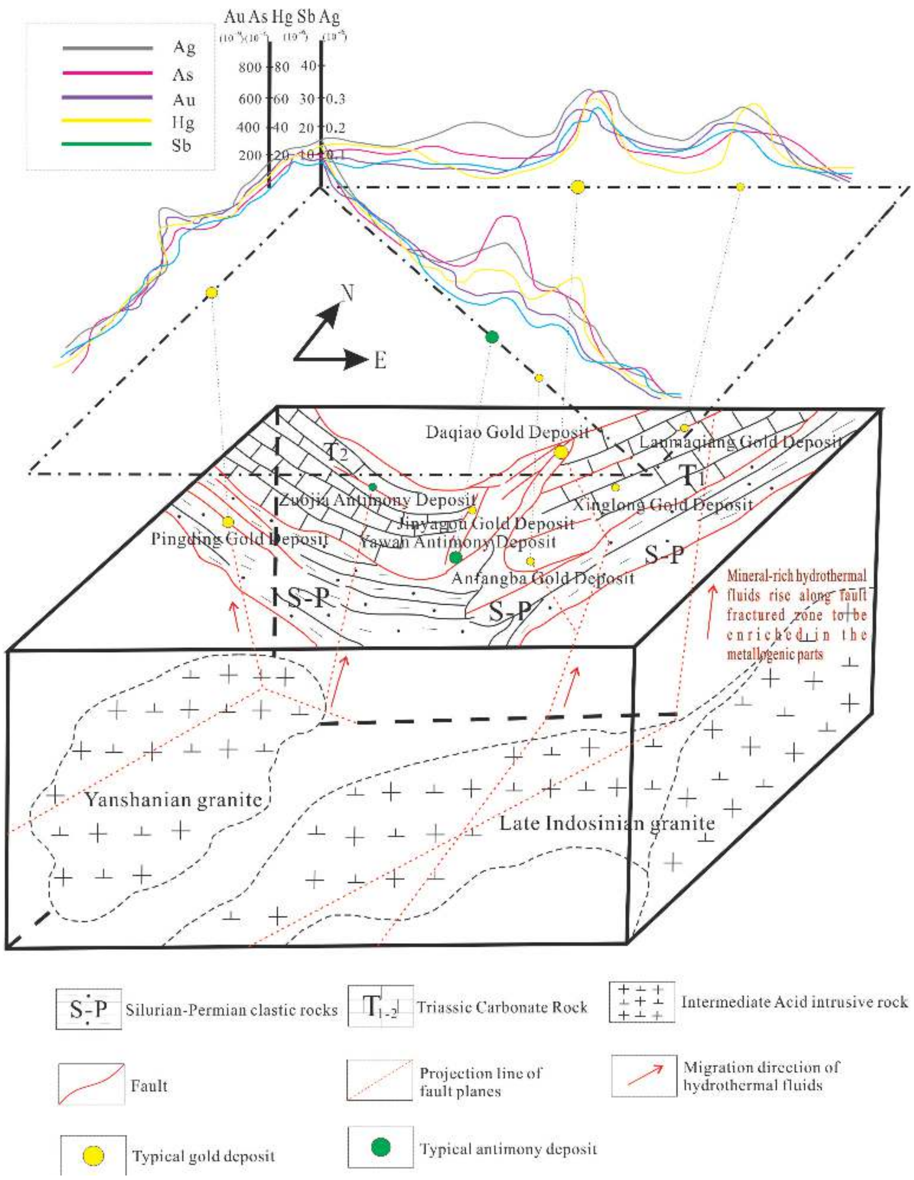

Fig. 3 Regional prediction model of the Yawan–Daqiao integrated exploration area

2.4.3.2 Preparation of Predictive Factor Maps

Predictive factor maps were prepared with the metallogenic factor map serving as the base map. To reflect the geophysical, geochemical, and remote-sensing predictive factors, the map layers of sedimentary suites and intrusive rock suites were deleted and only the lithological patterns were retained but faded. Meanwhile, the following factors were superimposed: (1) geophysical factors: the intermediate-acid plutons and structures interpreted; (2) chemical factors: Au-Hg-As-Sb composite anomalies, single element anomalies of Au, Sb, and As, and the intermediate-acid plutons interpreted; (3) metallogenic structures interpreted from remote sensing. In addition, the map layers of predictive factor data table and prediction models were inserted.

2.4.4 Prediction Result Maps

The typical deposits in Yawan–Daqiao integrated exploration area were determined temporally and spatially according to comprehensive factors of geological suites, deformed structures, and intrusive magmatism. Therefore, all mineral prediction methods used are of composite endogenous type. The prediction information was extracted based on the GIS assessment system for mineral prediction and presented in.wp files. It covers metallogenic structures (extracted according to the occurrence and properties of the metallogenic structures obtained from different prediction types; mitigation zones were built in combination with the frequency of the influence zones of metallogenic structures and ore occurrences), metallogenic geologic blocks (Late Indosinian–Yanshanian intermediate-acid intrusive bodies interpreted; mitigation zones were built in combination with the frequency of the influence zones of metallogenic structures and ore occurrences), ore-bearing suites, and geochemical anomalies (single element anomalies of Au, Sb, and As, and composite anomalies of Au-Hg-As-Sb). Afterwards, based on the prediction and assessment models, predicted minimum prospecting target areas (also referred to as the minimum predicted areas) were delineated by using the factor superposition method, applying the software MRAS to conduct interactive searches of modelers, and carrying out intersection and union operations of predictive factors. Then metallogenic probability was determined by manually selecting model units. In this study, the predicted minimum prospecting target areas were optimized in terms of denudation degree. As a result, 42 gold-antimony minimum predicted areas were determined, covering an area of 2.7% of the total area of the integrated exploration area. The areas for prediction assessment model were further established. The predicted depth and the ore-bearing coefficient of ore-bearing geologic blocks were calculated according to the parameters such as identified resources (above 333 resources), the area of ore vein concentration areas, and the maximum exploration depth. Moreover, the predicted resources was estimated according to the volume of ore-bearing geologic blocks.

The prediction result maps were compared based on predictive factor maps. On the prediction result maps, horizontal lines are used to fill in Class A predicted minimum areas (having very favorable metallogenic conditions and deposits), vertical lines are used to fill in Class B predicted minimum areas (having favorable metallogenic conditions), and cross lines are used to fill in Class C predicted minimum areas (having general metallogenic conditions). Meanwhile, annotations were made (including the nos., names, area, depth, similarity coefficient, predicted resource types, and categories of the predicted minimum areas). Finally, the map layers of various prediction tables were superimposed on the prediction result maps.

2.5 Value Assignment for Attributes of the Dataset

The attribute values of the dataset in this study were assigned by referring to the *Spatial Database Establishment Code of Digital Geological Maps* (DD2006–06) according to the *Code of Geological Information Metadata* (DD2006–05) issued by the China Geological Survey. Databases were established for various types of maps according to the *Method and Technology System of Data Models for Mineral Resources Potential Assessment* and the requirements of GeoMAG.

3 Description of Data Samples

Attribute values were assigned and corresponding databases were established for comprehensive suite-structure maps, magnetic survey maps, geochemical maps, remote sensing maps, metallogenic factor maps, predictive factor maps, prediction results maps, metallogenic regularity maps, and maps of suggestions on mineral exploration deployment. Since partial database units of the maps are inherited from other maps, only the database units specific to each type of maps are described as follows.

Database units specific to the suite-structure maps: (1) the attributes of a sedimentary rock suite, including its no., characteristic code, primitive no., category, rock associations, names and codes of its mapping units, genetic type of the Quaternary, formation time, suite type, thickness of ore-bearing strata, major fossil assemblages, and sedimentary facies; (2) the attributes of an intrusive rock suite, including its no., characteristic code, primitive no., lithologic code, geographical longitude and geographical latitude, names and codes of its mapping units, formation time, special rocks, mineral composition, the colors, texture, and structure of its rocks, occurrence of intrusions, dikes, inclusion characteristics, the depth and pattern of its emplacement, denudation degree, important petrochemical parameters, the series, genetic types, and tectonic associations of its rocks, and geotectonic setting; (3) attributes of a fault, including its no., name, length, type, fault plane dip (dip angle), rocks on both sides of and within the fault, structural hierarchy, cutting depth, motion mode, mechanical properties, formation time, and superimposed motion; (4) attributes of a fold, including its no., name (type, morphology, and degree), hinge plunge angle, plunge direction, axial dip (dip angle), strata involved in the fold, fold association form, genesis, formation time, and characteristics of superimposed folds; (5) attributes of occurrence, including its no., type, dip, dip angle, and strike.

Database units specific to magnetic survey maps, geochemical maps, and remote-sensing maps: (1) attributes of a fault, including its no., outcrops, order, strike, length, and magnetic field indicators; nos. and values of its aeromagnetic ΔT isolines and aeromagnetic ΔT RTP isolines, and the no., initial value, and end value of its isoline area; (2) attributes of single-element geochemical maps, including the nos., element composition, and element content of isolines; the element composition, maximum element content, and minimum element content of an isoline area; (3) attributes of single-element geochemical anomaly maps, including the anomy no. and threshold of a geochemical anomaly boundary; the no., anomaly threshold, local maximum/minimum points, anomaly no., and anomaly area of a geochemical anomaly range area; (4) attributes of geochemical anomaly maps, including the no., area, major associated elements, and major paragenetic elements of an integrated anomaly range, and the element types, anomaly threshold, measurement units, and anomaly area of major metallogenic factor ranges.

The database units specific to the metallogenic factor maps: the attributes of a mineral deposit, including its no., characteristic code, primitive no., name, traffic location, geographical longitude and latitude, ore-hosting rocks, ore-controlling structures, major minerals, geotectonic location, metallogenic types, the scale, resource reserves (unit), and average grade (unit) of its major minerals, paragenetic and associated minerals (reserves, unit), metallogenic zones/belts, metallogenic series, deposit type, metallogenic time, metallogenic age, age error, dating methods, spatial combination type of its ore bodies, the no. and shape (scale, strike, dip, dip angle, length, and thickness) of its major ore body, ore composition (grade, mineral composition, structure, and texture), length (width) of its alteration zones, and the alteration assemblages and alteration intensity of its surrounding rocks.

The database units specific to the prediction result maps: the nos., names, area, scale, and geographic locations of predicted minimum areas; metallogenic geological setting; mineral prediction types; predicted area categories; identified resources; estimation method of resources; reserves data table of predicted minimum areas (EXCEL).

The database units specific to the metallogenic regularity maps: boundary nos. and names of metallogenic zone/belts, ore concentration areas, and metallogenic prospect areas; the names of typical deposits.

The database units specific to the maps of suggestions on mineral exploration deployment: the no., name, grade, and mineral types of suggested deployment area, suggestions on mapping and exploration on a medium-large scale, expected results, and the data table of suggestions on mineral exploration deployment (EXCEL).

4 Data Quality Control and Assessment

The results of the mineral resource potential assessment in this study were all integrated into a dataset. To implement the mineral resource potential assessment and build the dataset, rich true and reliable data obtained previously were collected. Among the map sheets in the Yawan–Daqiao integrated exploration area, only Liangdang, Zhouqu, and Shawan map sheets had not been surveyed before. Therefore, the 1:250 000 regional geological survey data of Minxian, Tianshui, Wudu, and Lueyang County map sheets along with cross-sections were adopted to prepare the comprehensive suite-structure maps. Meanwhile, the newly collected grid data with a cell size of 500 m ×500 m were integrated, and the 1：50 000 geochemical data were processed. All data processing strictly followed the *Technical Guidelines for* 1：50 000 *Mineral Resource Potential Assessment of Integrated Exploration Areas (Draft)* developed by the Exploration Technical Guidance Center of the Ministry of Natural Resources of the People's Republic of China in 2018. With reliable data sources, databases were constructed according to the *Method and Technology System of Data Models for Mineral Resource Potential Assessment* (Development and Research Center of China Geological Survey, 2016), achieving complete attributes.

The dataset was developed under the strict control of a three-level quality inspection system and the quality system of the Gansu Institute of Geological Survey. In early January 2019, the Development and Research Center of China Geological Survey (i.e., the Technical Guidance Center for Mineral Resources of Ministry of Natural Resources) organized experts to review the research report and database specific to the 1：50 000 mineral resource potential assessment of the gold-antimony deposit integrated exploration area in Yawan–Daqiao area, Gansu Province. The expert panel unanimously approved the research report and database and rated them excellent.

5 Data Value

(1) Under the guidance of the "trinity" prospecting prediction theory, the predictive factors of the Daqiao gold deposit, Pingding gold deposit, and Yawan antimony deposit were sorted out and prediction models were built.

(2) The metallogenic regularity of the Yawan–Daqiao integrated exploration area was researched based on the metallogenic regularity of west Qinling area. As a result, two Level-IV metallogenic zones and six Level-V ore concentration areas were determined according to the national mineral resource potential assessment results and the division of Level-III metallogenic zones/belts throughout China. Moreover, eight Grade-V gold-antimony metallogenic prospect areas were determined according to the mineral resource prediction results of this study.

(3) A series of aeromagnetic maps of the integrated exploration area were prepared through collecting and collating the aeromagnetic data with different precision, such as the grid data with a cell size of 500 m ×500 m. The aeromagnetic maps developed include 1：50 000 aeromagnetic survey degree maps, aeromagnetic (ΔT) isoline plans, aeromagnetic (ΔT) RTP isoline plans, and aeromagnetic (ΔT) RTP-based vertical first-order derivative maps. Moreover, the interpretation of plutons and structures was further explored and updated in terms of data, which is indirectly indicative of mineral prediction.

(4) The 1：50 000 geochemical data of the map sheets in the Yawan–Daqiao integrated exploration area were integrated into the dataset. Based on this, 597 single-elements anomalies and 59 integrated anomalies of 15 elements such as Au were delineated and two intermediate-acid plutons were interpreted. The research results of the denudation degree played a significant role in the mineral resource potential prediction of this study.

(5) The predicted resources in deep and peripheral areas of typical deposits in the integrated exploration area were delivered, including 190 419 kg in the Daqiao gold deposit, 7 492 kg in the Pingding gold deposit, and 99 568 tonnes in the Yawan antimony deposit. Meanwhile, 17 predicted minimum areas of Daqiao-type stratabound-hydrothermal gold deposits were delineated, with 353 470.26 kg of predicted gold resources being delivered; 10 predicted minimum areas of Pingding-type structural-hydrothermal gold deposits were delineated, with 107 171.85 kg of predicted gold resources being delivered; 15 predicted minimum areas of Yawan-type structural-hydrothermal antimony deposits were delineated, with 587 889.43 tonnes of predicted antimony resources being delivered.

(6) A total of 12 exploration areas were deployed according to the mineral resource prediction results in this study, including three Level I, three Level II, and six Level III exploration areas. Among them, the three Level I exploration areas are Chaerjin-Pingding exploration area, Daqiao exploration area, and Miaowan-Paierba exploration area, and the three Level II exploration areas are Longba exploration area, Anfangba exploration area, and Nanjiashan exploration area. Specially, 37 secondary exploration areas were deployed, including 15 reconnaissance survey areas and 22 pre-investigation areas. The predicted gold and antimony resources are 460.67 tonnes, and 587 900 tonnes, respectively.

6 Conclusions

(1) The 1：50 000 mineral resource potential assessment of the gold-antimony deposit integrated exploration area in Yawan–Daqiao area, Gansu Province is a demonstration project of potential assessment in the new round of mineral geological survey and prospecting prediction projects of integrated exploration areas initiated by the China Geological Survey. In this study, the authors of this paper actively explored and innovated a series of working methods and map compilation methods for potential assessment of integrated exploration areas, and established a potential assessment dataset. All these provide an example for the 1：50 000 potential assessment of integrated exploration areas throughout China in terms of working contents, working processes, and the establishment of datasets.

(2) To carry out the mineral resource potential assessment in this study, previous research results and data were sorted out and integrated. Therefore, the establishment of the dataset in this study is of significant for relevant data collation and integration.

(3) The sedimentary rocks and intrusive rocks in the Yawan–Daqiao integrated exploration area were comprehensively researched using the latest basic geological data and scientific research data of the area. Accordingly, comprehensive suite-structure maps (1：50 000) of the area were prepared, providing basic information of the metallogenic geological setting for research on metallogenic regularity and mineral resource prediction. Meanwhile, practical and feasible working procedures were summarized. All these assist in improving the degree of basic geological research in the area. Meanwhile, the dataset established in this study will provide data bases for subsequent exploration in this area.

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